Determination of Wettability from Magnetic Resonance Relaxation and Diffusion Measurements on Fresh-State Cores

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Abstract

Reservoir wettability is a critical parameter affecting hydrocarbon distribution within reservoir rocks, and ultimately, its recovery. We demonstrate a novel method to estimate wettability based on two-dimensional map of NMR diffusion vs. T2 with three principal advantages. First, the separation between the oil and water signals is greatly improved compared with the T2 only based approach with the added diffusion dimension. Second, key properties such as tortuosity (represented by the Archie cementation exponent *m*) and effective surface relaxivity can be inverted from the two-dimensional NMR maps by fitting the mean diffusion data to a generalized diffusion model (i.e. diffusion is free in large pores and restricted in small pores). Third, the processing takes a few seconds once the NMR data is acquired as compared to the long saturation and desaturation measurement cycles needed in Amott or U.S. Bureau of Mines (USBM) procedures. The wettability index can then be estimated from the effective surface relaxivities of oil and water. Here, "effective relaxivity" is defined as the rock relaxivity under the fluid partial saturation. These results are based on a single-step NMR measurement on fresh-state (or “as received”) plugs cored with water-base muds containing no surfactants that should be available days after the cores are recovered. A wettability index using this new NMR method was obtained for carbonate samples from Middle East reservoirs. A strong correlation coefficient of $R2 = 0.7$ is observed between this new NMR approach and the standard USBM technique. A sensitivity study of the NMR wettability index versus signal-to-noise ratio is performed on the core data to assess the feasibility of this new technique down hole. The results suggest that it is possible to obtain reservoir wettability using downhole NMR measurements under appropriate conditions.